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IN THE APPLICATION

OF

GREGORY M. MAROCCO

FOR A

CATALYTIC CONVERTER AND RESONATOR COMBINATION

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CATALYTIC CONVERTER AND RESONATOR COMBINATION

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates generally to automobile exhaust emission control, and more specifically to a device combining a catalytic exhaust converter and a resonator installed within the exhaust system for the reduction of exhaust noise. Several embodiments are disclosed herein, for single and dual exhaust systems and for single and plural catalytic converter elements therein.

2. DESCRIPTION OF THE RELATED ART

By the time of the 1950s, it was becoming apparent that the ever increasing volume of automobile and truck traffic was generating exhaust emissions which were adversely affecting the environment. This was particularly true in urban areas and other areas where geographic and meteorological conditions combined to create areas where such emissions do not readily dissipate. Accordingly, by the late 1960s, various regulations were being implemented to require equipment to reduce exhaust emissions output from automobiles, particularly in California and other urban areas.

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While early emissions control efforts provided some relief, standards have become increasingly strict in order to keep pace with the ever increasing volume of automobile and truck traffic throughout the U. S. A. With the development of the catalytic converter, which uses one or more noble metals such as platinum, rhodium, and/or palladium to produce an oxidizing and/or reducing catalytic reaction with the exhaust products and heat generated by the exhaust, a real breakthrough was achieved in the control of vehicle emissions. An automobile equipped with one or more catalytic converters was capable of meeting most, if not all, of the exhaust emissions standards of the time, and the use of catalytic converters became commonplace on automobiles and light trucks powered by spark ignition engines in the U. S. A.

However, long before the recognition of chemical or particulate automobile exhaust emissions as a hazard, another type of automobile exhaust emission had been recognized, i. e., noise or sound. In fact, legislation in virtually every area of the world requires motor vehicles to have equipment which reduces this other emission. Accordingly, mufflers, resonators and other such sound attenuating devices have been known for many years, since shortly after the very earliest development of the internal combustion engine. These two types of emissions control devices, i. e., catalytic converters and mufflers or other sound attenuating devices, have generally not been combined into a single unit due to conflicting characteristics and physical requirements.

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In the case of exhaust silencing devices, the maximum desired temperatures for such devices in operation are generally relatively low in comparison to the temperatures achieved in catalytic converters. Mufflers, resonators, and such sound attenuating devices are generally constructed of mild steel, perhaps with an aluminized exterior coating. Very high temperatures cause the aluminized coating to be burned off, and cause both the interior and (after removal of any coating) exterior to be oxidized, to the point of burn through or rust through, in relatively short order. While mufflers and other related devices have been constructed of stainless steel in order to reduce oxidation problems, these devices are relatively costly due to the material used and the difficulty in working with such material, in comparison to mild steel. Many, if not most, automobile owners would rather replace a standard steel exhaust system once or twice during their ownership of the car, rather than pay for a replacement system which costs perhaps three times that of a standard, mild steel system.

On the other hand, catalytic converters require relatively high temperatures for efficient operation. If a catalytic converter does not reach a minimum temperature, the catalytic reactions therein will be greatly reduced. Thus, most catalytic converters are constructed of relatively costly materials in order to withstand the heat generated therein. Even so, most converters are installed at some distance from the engine, in order to preclude being subjected to excessive heat which could damage them.

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While mufflers are generally installed toward the extreme downstream end of the exhaust system, many exhaust systems also incorporate a resonator. Resonators are also sound attenuation devices, but operate on a completely different principle than that of the muffler. The muffler is adapted to cancel most sounds therein by reflecting the sounds (and the exhaust) back and forth through a series of parallel pipes therein, and by forcing the exhaust gases laterally outwardly through relatively small passages in the pipes. The resonator is adapted to pass the exhaust gases therethrough with little or no impedance, while canceling or absorbing sounds within a certain relatively well defined frequency range. This range is generally relatively high, with the muffler being relied upon for the attenuation of lower exhaust frequencies.

As the resonator is adapted to attenuate different frequencies than the muffler, and operates on a different principle, it is generally placed elsewhere in the exhaust system, somewhat forwardly of the muffler. This is also the general area in which catalytic converters are typically installed in an automobile, in order to avoid excessive exhaust heat while still accepting sufficient exhaust heat to function. While resonators do not generate internal heat due to chemically reacting the exhaust products, as do catalytic converters, they still must be structured to accept a relatively high exhaust temperature due to their location relatively near the engine. However, heretofore no combining of a catalytic converter and a resonator has been accomplished, to the knowledge of the present inventor.

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Accordingly, a need will be seen for a catalytic converter and resonator combination which serves both purposes in a single device. The device may be installed in a conventional automobile exhaust system, between the engine and a conventional muffler and/or tailpipe. Different embodiments may be provided for single and dual exhaust systems, each of which may include one or more catalytic converter elements or "bricks." When used with a pre-catalytic converter, a muffler for further sound attenuation may not be required, depending upon the particular automobile, engine, and exhaust system. A discussion of the related art of which the present inventor is aware, and its differences and distinctions from the present invention, is provided below.

U. S. Patent No. 4,050,903 issued on September 27, 1977 to Charles H. Bailey et al. describes a Combination Muffler And Catalytic Converter, having a relatively convoluted exhaust gas flow path therethrough. The exhaust gases enter through a venturi, which is used to draw air into the exhaust to mix therewith. (It is noted that mufflers are inherently pressurized somewhat higher than ambient when in operation, due to the backpressure created in such devices, yet Bailey et al. do not utilize any other means than the venturi effect to introduce the air into the muffler.) The exhaust and air are mixed by a deflector cone extending into the outlet of the venturi. From this point, the exhaust mixture passes through a series of holes in a transverse plate, and thence through holes in another plate to enter the catalytic converter. The present catalytic converter and resonator combination is a straight

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through, axial flow, free flow configuration, adapted for the attenuation of specific frequencies, unlike the muffler configuration of Bailey et al. Also, the catalytic converter element of the present invention is located within the forward portion of the device, where it is subjected to the highest possible exhaust heat which occurs within the entire device. Bailey et al. locate their catalytic converter element in the rearward portion of the device, where the exhaust gases have cooled somewhat by their passage through the convoluted flow path of the forward muffler portion of the device. As the muffler itself is generally located to the rear of the exhaust system, some efficiency would be lost in the Bailey et al. device, due to the relatively cooler exhaust temperatures by the time the exhaust gases arrive at the catalytic converter element.

U. S. Patent No. 4,425,304 issued on January 10, 1984 to Masayuki Kawata et al. describes a Catalytic Converter comprising a single shell or container with two converter units or "bricks" installed in series therein. No sound attenuating means is disclosed by Kawata et al. in their catalytic converter.

U. S. Patent No. 4,426,844 issued on January 24, 1984 to Keiichi Nakano describes an Engine Muffler Of Heat-Exchanging Type, incorporating a pair of catalytic converter components therein. The two catalytic converter components are positioned in front of the heat exchanger, which also acts as a muffler. Exhaust gas flow enters the device by means of a radial pipe, and flows radially to enter and exit the myriad of axial heat exchange passages in the

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muffler and heat exchanger element. In contrast, the present invention provides for strictly straight through, axial flow of exhaust gases therethrough, in order to reduce back pressure therein and provide the greatest possible free flow of the exhaust gases. The present device is not a muffler, with a convoluted and restrictive flow path, but rather is a resonator, adapted for the reduction or canceling of certain specific exhaust gas frequencies.

U. S. Patent No. 5,043,147 issued on August 27, 1991 to Glen Knight describes a Combined Muffler And Catalytic Converter Exhaust Unit, with a pair of converters being installed within the first portion of the muffler shell. The exhaust gases are then forced to travel a sinusoidal, convoluted path forward and aft through the muffler portion, with gases being exchanged between various pipes within the muffler portion due to perforations provided through the pipes. The present straight through, free flow resonator provides greatly reduced back pressure, in comparison to a muffler configuration such as the Knight apparatus. The disadvantages of including catalytic converters within a muffler located toward the outlet end of the exhaust system, with its reduced heat, have been noted further above in the discussion of the patent to Bailey et al., and apply here as well.

U. S. Patent No. 5,108,716 issued on April 28, 1992 to Kimiyoshi Nishizawa describes a Catalytic Converter having two converter components housed within a single container or shell. No sound attenuation means is disclosed by Nishizawa, as provided by the present catalytic converter and resonator combination.

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U. S. Patent No. 5,265,420 issued on November 30, 1993 to Erwin Rutschmann describes an Exhaust System Of A Multi-Cylinder Reciprocating Engine, in which a single catalytic converter is provided for each cylinder bank of a V-8 engine. Exhaust gases pass through the two catalytic converters, thence to a single transverse muffler. Thus, Rutschmann requires three separate housings or units for the two catalytic converters and single muffler of his system, whereas the present catalytic converter and resonator combination are combined within a single housing. Also, the Rutschmann system does not provide straight through flow, but requires the exhaust gases to make several turns between the catalytic converters and the transverse muffler inlet and outlet. No resonator is disclosed by Rutschmann.

U. S. Patent No. 5,325,666 issued on July 5, 1994 to Erwin Rutschmann describes an Exhaust System Of An Internal Combustion Engine, somewhat similar to the apparatus of the '420 U. S. Patent to the same inventor, discussed immediately above. The convoluted routing of the exhaust gases, the use of separate housings or components for the catalytic converters and mufflers, the use of a plenum around the catalytic converters, and other differences, make the Rutschmann apparatus distinct from the present catalytic converter and resonator combination. Again, it must be noted that a muffler is not a resonator, and does not provide straight through flow of exhaust gases and the attenuation of a relatively narrow range of frequencies.

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U. S. Patent No. 5,378,435 issued on January 3, 1995 to Albino Gavoni describes a Silencer Combined With Catalytic Converter For Internal Combustion Engines And Modular Diaphragm Elements For Said Silencer. The device is essentially a cylindrical container with a series of cup-shaped catalytic converter elements arranged therein. The elements are each relatively thin, due to the cup-like shape of each element, and thus do not present a significant cross sectional area to the exhaust gases passing therethrough. Thus, a great many such elements are required, unlike the present catalytic converter and resonator combination. Moreover, the exhaust gas flow through the device, at least at the entrance thereto, is not axial, but passes radially through a plurality of lateral openings in a conical inlet pipe, unlike the straight through, axial flow configuration of the present system.

U. S. Patent No. 5,398,504 issued on March 31, 1995 to Tomotaka Hirota et al. describes a Layout Structure Of Catalytic Converters, in which first and second converters are installed immediately adjacent the respective cylinder banks of a V-configuration engine. A separate third, main converter is provided beneath the engine. Each of the converters is contained in a separate housing or shell, unlike the combined catalytic converter and resonator of the present invention. Moreover, Hirota et al. do not disclose any form of exhaust silencing or noise attenuating means in their system, as is provided by the present catalytic converter and resonator combination.

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Japanese Patent Publication No. 55-43262 published on March 27, 1980 illustrates an exhaust gas purifier in which the catalytic converter unit includes a baffle within its inlet end to preclude interference between exhaust gases alternatingly entering the converter from the no. 1 and no. 4 cylinders, and the no. 2 and no. 3 cylinders. No muffler, resonator, or other sound attenuating means is apparent, as is provided in the present catalytic converter and resonator combination invention.

Finally, Japanese Patent Publication No. 57-41414 published on March 8, 1982 illustrates a method of manufacturing a catalytic converter equipped with a muffler. The assembly includes a forward muffler with a catalytic converter welded thereto and downstream thereof, with a rear muffler welded to the downstream end of the catalytic converter. The present catalytic converter and resonator combination utilizes a single, monolithic shell enclosing both the catalytic converter and resonator components, with no welding of separate components being required to form the housing or shell for the device. A "protector 37" (per the English abstract), apparently comprising an outer shell spaced apart from the inner housing containing the catalytic converter, is welded over the remainder of the assembly, unlike the present catalytic converter and resonator combination with its single shell or housing. No disclosure is apparent regarding any provision for a straight through, free flow resonator, as provided by the present invention.

None of the above inventions and patents, either singly or in combination, is seen to describe the instant invention as claimed.

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SUMMARY OF THE INVENTION

The present invention comprises a catalytic converter and resonator combination, combined within a single canister or shell (i.e., a one piece unit). The combination device may be installed between the engine and a muffler at or near the downstream or exhaust outlet end of the exhaust system, with the system perhaps including an additional catalytic converter(s) upstream of the catalytic converter and resonator combination. The placement of the present catalytic converter and resonator combination forward of the muffler and tailpipe of the exhaust system, with the converter element forward of the resonator element, ensures that the converter portion of the combination will receive exhaust gases at a sufficiently high temperature to produce the desired catalytic reaction and thereby oxidize and/or reduce the exhaust components to harmless products. The catalytic converter element may be formed of a thin wall ceramic material, for further efficiency.

The resonator portion of the present combination is a straight through, free flow configuration, with all components being concentric to one another in the single exhaust configuration for greater efficiency. The resonator includes a central pipe with a plurality of relatively small holes or passages therethrough, for attenuating or canceling a relatively narrow band of frequencies produced by the engine exhaust. An alternative embodiment may include a dual exhaust version, with two side by side resonator pipes behind the catalytic converter portion, and either embodiment may include one or more catalytic converter elements therein.

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As noted above, a resonator operates on the principle of canceling or impeding certain frequencies of sound within a relatively narrow band or range. The loudest sounds produced by various internal combustion engines will vary in frequency, depending upon the engine configuration (number of cylinders, cylinder layout, etc.), and other factors, including installation, etc. Accordingly, it is important to be able to adjust or tune a resonator for a given installation, in order to attenuate sounds within a predetermined range. The present combination catalytic converter and resonator invention may be structured to provide for such adjustment at the time of manufacture or assembly, as desired. Also, additional sound absorbing material may be installed within the device if desired, surrounding the inner resonator pipe or tube, to absorb sounds which might otherwise be transmitted through the outer shell of the device.

Accordingly, it is a principal object of the invention to provide an improved catalytic converter and resonator combination comprising a straight through, axial flow, free flow configuration having at least one catalytic converter element in the forward portion thereof, with a concentric resonator pipe positioned behind the at least one catalytic converter component.

It is another object of the invention to provide an improved catalytic converter and resonator combination which catalytic converter element may have a substrate formed of a strong and heat resistant thin wall ceramic material.

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It is a further object of the invention to provide an improved catalytic converter and resonator combination which may alternatively comprise a dual exhaust configuration, with two side by side resonator pipes disposed behind one or more catalytic converter elements within a single monolithic shell.

An additional object of the invention is to provide an improved catalytic converter and resonator combination which may include one or more catalytic converter elements concentrically in series therein.

Still another object of the invention is to provide an improved catalytic converter and resonator combination which may be adjusted or tuned at the time of assembly to attenuate sounds in a specific predetermined range, and which may include further sound absorbing materials therein to reduce sound transmission through the shell thereof.

It is an object of the invention to provide improved elements and arrangements thereof in an apparatus for the purposes described which is inexpensive, dependable and fully effective in accomplishing its intended purposes.

These and other objects of the present invention will become apparent upon review of the following specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view in partial section of a single exhaust catalytic converter and resonator combination of the present invention, showing its structure and features.

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Figure 2 is a perspective view in partial section of an alternative embodiment of the device of Figure 1, showing the adjustability of the inner resonator tube during assembly for attenuating a predetermined range or band of sound frequencies, and including further sound absorbing materials therein.

Figure 3 is a perspective view in partial section of an alternative embodiment of the single exhaust catalytic converter and resonator combination of Figure 1, incorporating dual concentric catalytic converter elements therein.

Figure 4 is a perspective view in partial section of another alternative catalytic converter and resonator combination, with two side by side resonators behind a single catalytic converter.

Figure 5 is a perspective view in partial section of an alternative embodiment of the device of Figure 4, incorporating dual concentric catalytic converter elements therein.

Figure 6 is a detailed front elevation view of the substrate element and flow passages of the present catalytic converter element showing the thinner walls and larger passages therethrough.

Figure 7 is a detailed front elevation view of a prior art substrate element for a catalytic converter, showing the relatively thick walls and narrow passages therethrough.

Figure 8 is a flow chart showing the preferred installation of the present catalytic converter and resonator combination in an exhaust system.

Similar reference characters denote corresponding features consistently throughout the attached drawings.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention comprises several different embodiments of a catalytic converter and resonator combination. The present invention includes at least one (or more) catalytic converter element(s) within the same canister or shell used to house an exhaust resonator, which is normally used for the attenuation or canceling of exhaust noise or sound in a relatively narrow frequency range. Such resonators generally include a plurality of relatively small perforations therein, with the size of the perforations being configured according to the frequency or frequencies which are to be attenuated or canceled. Resonators are not mufflers, in that they do not serve to attenuate or cancel a broad range of exhaust frequencies, but rather reduce or eliminate certain objectionable frequencies or levels which are more difficult to attenuate using a conventional muffler.

Such resonators, if used, are generally installed in an exhaust system forwardly of the conventional muffler, between the muffler and the engine exhaust manifold or catalytic converter downstream (i. e., in the direction of exhaust gas flow) from the manifold. Accordingly, resonators accept a fair amount of exhaust heat, somewhat more than that seen by the muffler near the outlet end of the exhaust system. As catalytic converters require a certain minimum amount of heat for efficient operation of the catalytic reaction(s) occurring therein, the present invention combines at least one catalytic converter with a resonator, where the converter may receive a reasonable amount of exhaust heat.

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A first embodiment of the present catalytic converter and resonator combination is shown in Figure 1, and is designated by the reference numeral 10. The embodiment 10 of Figure 1 comprises a hollow, monolithic tubular canister or shell 12, having a forward or inlet end 14, a forward portion 16 immediately behind and adjacent the inlet end 14, a rearward portion 18 immediately behind and adjacent the forward portion 16, and a rear or outlet end 20 immediately behind and adjacent the rearward portion 18. The forward portion 16 has an inner diameter 22 which is dimensioned to accept at least one catalytic converter element 24 therein, with the catalytic converter element 24 installed therein having an outer diameter (also designated by the reference numeral 22) substantially equal to the inner diameter 22 of the canister 12. The rear portion 18 of the canister 12 has an inner diameter 26 dimensioned to accept a resonator element therein.

The catalytic converter element 24 includes a substrate 28 having a plurality of longitudinal passages 30 therethrough, with each of the passages 30 being defined by a plurality of walls 32, as shown in detail in Figure 6. These walls 32 may be generally horizontally and vertically oriented to form a honeycomb or grid-like configuration when viewed in lateral cross section, as shown in Figure 6. Each of the walls 32 is coated with one or more catalytically reactive elements or materials, e. g., noble metals such as platinum, palladium, rhodium, etc., as is known in the art.

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The efficiency of the present converter 24 is increased by constructing the substrate 28 with the walls 32 having a relatively thin (e.g., 0.010" maximum) cross section and the passages 30 therebetween being relatively wide, in order to reduce the restriction to exhaust gas flow as much as possible. A comparison of the present substrate 28, note Figure 6, with a prior art substrate S shown in Figure 7, clearly shows the wider passages 30 of the present substrate 28. The walls W of conventional substrates, such as the substrate S shown in Figure 7, are relatively thick due to the need for structural strength at the elevated temperatures occurring within catalytic converters. These walls W are normally somewhat thicker than required for structural strength at normal temperatures, but due to the extremely elevated temperatures occurring within a catalytic converter, they must be made even thicker to provide the required structural strength at such elevated temperatures where most materials are weakened.

The relative thickness of the walls W of conventional catalytic converter substrates S results in the passages P therebetween having a relatively narrow width, as may be seen in a comparison of a conventional catalytic converter substrate cross section in Figure 7 and the substrate 28 of the present catalytic converter and resonator invention. Typically, such conventional passages P have a width on the order of .040 inch, for a passage cross sectional area of about .0016 inch. Wider passages, with the walls therebetween being spaced further apart, would not provide the required structural strength at the elevated temperatures occurring within such conventional catalytic converters.

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On the other hand, the catalytic converter substrate 28 of the present catalytic converter and resonator combination 10 has passage widths substantially greater than .040 inch, preferably on the order of .050 inch for a passage cross sectional area of .0025 inch, or over half again as great an area as the conventional catalytic converter passage P. Yet, the number of passages 30 in a given cross sectional area of the present substrate 28 closely approaches that of the passages P in a conventional converter substrate S, due to the relatively thin substrate walls 32 of the present converter substrate 28. Due to their relatively high surface area per pass and volume ratio, the thin substrate walls 32 serve to absorb heat more quickly than the relatively thick walls W of prior art substrates S. This allows the present catalytic converter element 24 to reach its normal operating temperature more quickly than catalytic converters of the prior art, thus reducing the "cold start" period when emissions are relatively high due to the need for exhaust gases to warm up the converter to reach an optimum temperature for the catalytic reactions to occur efficiently. Thus, the catalytic converter 24 of the present catalytic converter and resonator combination 10 reduces the period of time following a cold start when exhaust emissions are relatively high due to the catalytic converter being relatively cool.

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While conventional converter substrates S have been formed of relatively expensive metals in order to provide the required structural strength at the elevated temperatures found in such devices, the catalytic converter 24 of the present catalytic converter and resonator combination or device 10 preferably uses a ceramic material for the substrate walls 32. Such ceramic materials provide excellent resistance to heat, but a relatively strong material is required in order to provide the required structural strength, particularly in the case of the relatively thin substrate walls 32 of the present invention. A ceramic material known as Dow-Corning XT (tm), such as cordierite ceramic, manufactured by the Dow-Corning Company, has been found to be suitable for the construction of such thin wall catalytic converter substrates 28 of the present invention. Other materials providing sufficient structural strength at the elevated temperatures experienced within an operating catalytic converter, may be used as desired.

The canister rearward portion 18 includes a resonator element 34 installed therein. The resonator element 34 is a generally tubular or cylindrical device, which may be rolled from a flat sheet of suitable metal or otherwise formed. The resonator element 34 has a hollow core 36, a forward end 38, an opposite rearward end 40, and an outer diameter 42 which is substantially less than the inner diameter 26 of the rear portion 18 of the canister 12. This difference between the inner diameter 26 of the canister rearward portion 18 and the outer diameter 42 of the resonator element 34, defines a sound attenuating plenum 44 therebetween.

The resonator element 34 includes a plurality of sound attenuating perforations 46 formed radially therethrough, for the attenuation of exhaust sound in a relatively narrow range of frequencies. The passages or perforations 46 may be dimensioned and spaced to accommodate different frequency ranges as desired, as is known in the art.

The resonator element 34 is secured concentrically within the canister rearward portion 18 by a forward plate 48 and opposite rearward plate 50, affixed respectively to the forward end 38 and rearward end 40 of the resonator tube element or pipe element 34 and within the rearward portion 18 of the canister 12, normal to the axis of the resonator pipe element 34 and canister 12. These two plates 48 and 50 are toroid shaped, to allow exhaust gases to pass from a plenum 52 disposed between the catalytic converter element 24 and the forward end 38 of the resonator tube element 34, through the central passage of the forward plate 48 and thence through the hollow core 36 of the resonator pipe element 34 and out through the central passage of the rearward plate 50, as indicated by the exhaust gas arrows G.

The essentially equal diameters 22 of the catalytic converter element 24 and inner surface of the forward portion 16 of the canister 12 serve to affix the catalytic converter element 24 concentrically within the canister 12. The tight fit of the catalytic converter element 24 within the forward portion 16 of the canister 12, provides a tight seal between the catalytic converter element 24 and forward portion 16 of the canister 12, thereby precluding any bypass flow of exhaust gases therebetween.

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The toroidal plates 48 and 50 serve to secure the resonator pipe element 34 concentrically within the rearward portion 18 of the canister 12, with the tight fit of the catalytic converter element 24 within the forward portion 16 of the canister 12 serving to secure the converter element 24 concentrically therein. Thus, it will be seen that all of the above elements, i. e., the canister 12 with its inlet and outlet ends 14 and 20, catalytic converter 24, and resonator element 34 with its hollow core 36, are disposed concentrically relative to one another and are axially aligned with one another to provide a straight through, low restriction, free flow path for engine exhaust through the catalytic converter and resonator combination 10.

As noted further above, the resonator ~~portion 34~~ pipe element 34 of the present invention functions by attenuating sound of a predetermined frequency range, by means of the relatively small perforations 46 therethrough, and nearly all of the exhaust gases G pass through the resonator pipe hollow core 36. However, depending upon the relative pressures between the resonator core 36 and the resonator plenum 44, some exhaust gases may flow into the plenum 44. Accordingly, the rearward resonator attachment plate 50 may include one or more generally peripheral passages 54 therethrough, for allowing exhaust gases to depart the resonator plenum 44 and exit the canister 12 from the outlet end 20 thereof. The forward resonator attachment plate 48 may be formed with a solid periphery, to preclude the flow of exhaust gases from the converter and resonator plenum 52, directly into the resonator plenum 44.

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As noted further above, resonators serve to attenuate sounds in only a relatively narrow band or range of frequencies, depending upon their construction. The range of frequencies damped by a given resonator, is primarily dependent upon the length of the internal resonator element or pipe therein, with shorter elements resulting in the control of relatively higher frequencies, and longer elements being adapted for the reduction of relatively lower frequencies. As the predominant frequencies emitted by a given internal combustion engine will be dependent upon the configuration of the engine, it will be seen that it is desirable to provide some means for adjusting a resonator configuration for a given installation. Such adjustability may be important even for different resonators to be used with identical engines in identical exhaust systems, but in different vehicles, due to different resonant qualities of the specific vehicle structure.

Accordingly, the present invention provides for adjustment or tuning of the resonator frequency response band, by means of the combination catalytic converter and resonator 60 of Figure 2. The converter and resonator combination 60 is constructed similarly to the converter and resonator combination 10 of Figure 1, having a hollow, monolithic tubular canister or shell 62 with a forward or inlet end 64, a forward portion 66 immediately behind and adjacent the inlet end 64, and a rearward portion 68 immediately behind and adjacent the forward portion 66. However, the rearward portion 68 terminates in a conical section 70, which has a minor diameter equal to the diameter of the resonator element 72 therein.

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The forward portion 66 is essentially identical to the forward portion 16 of the converter and resonator combination device 10 of Figure 1, with the forward portion 66 being dimensioned to hold and secure at least one catalytic converter element 24 therein. The element 24 of the device 60 of Figure 2 is identical to the element 24 of the device 10 of Figure 1, having a substrate 28 with a plurality of longitudinal passages 30 therethrough defined by walls 32, as shown in detail in Figure 6. The specific structural details and materials of the catalytic converter 24 have been discussed in detail further above in the discussion of the converter and resonator combination 10 embodiment of Figure 1, and need not be repeated here.

The canister rearward portion 68 includes a resonator element 72 installed therein, constructed generally in the same manner as that described for the resonator element 34 of the embodiment 10 of Figure 1. The resonator element 72 of the embodiment ~~68~~ 60 of Figure 2 has a hollow core 74, a forward end 76, and an opposite rearward end 78, which also comprises the rear or outlet pipe for the converter and resonator combination or device or embodiment 60 of Figure 2. The forward portion of the resonator element 72 is formed essentially identically to the resonator element 34 of the device 10 of Figure 1, having a plurality of relatively small sound attenuating perforations or passages 80 formed through the wall thereof. The forward end 76 of the resonator 72 is secured concentrically within the canister rearward portion 68 by a forward plate 82.

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It will be seen that the rear portion of the embodiment 60 of Figure 2 differs from that of the embodiment 10 of Figure 1, in that there is no need for a rearward resonator element support plate in the embodiment 60 of Figure 2. As the resonator element 72 extends rearwardly from the rear conical portion 70 of the shell 62, the rear portion or rearward end or outlet end 78 of the element 72 is supported by the smaller diameter, necked down end portion 84 of the conical portion or section 70, and is welded at that joint to provide a leakproof seal at the time of manufacture or assembly. Accordingly, the rearward portion 78 of the resonator tube 72 is devoid of perforations, in order to provide a leakproof outlet for exhaust gases passing through the device 60 and onward to a trailing exhaust pipe (not shown) conventionally connected to the outlet end 78 of the resonator pipe element 72.

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The remainder of the catalytic converter and resonator combination 60 of Figure 2 is constructed similarly to the embodiment 10 of Figure 1, with the resonator element 72 having an outer diameter substantially less than the inner diameter of the rear portion 68 of the canister 62. This difference between the inner diameter of the canister rearward portion 68 and the outer diameter of the resonator element 72, defines a sound attenuating plenum 86 therebetween. A forward sound attenuating plenum 88 is also defined between the rear of the catalytic converter element 24 and the forward end 76 of the resonator element 72 and its supporting front plate 82, within the outer shell 62 of the combination catalytic converter and resonator device 60.

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The toroidal front plate 82, along with the necked down rearward end portion 84 of the conical rearward portion 70 of the shell 62, serve to secure the resonator pipe element 72 concentrically within the rearward portion 68 of the canister 62, with the tight fit of the catalytic converter element 24 within the forward portion 66 of the canister 62 serving to secure the converter element 24 concentrically therein. Thus, it will be seen that all of the above elements, i. e., the canister 62 with its inlet end 64 and necked down rearward end portion 84, catalytic converter 24, and resonator element 72 with its hollow core 74, are disposed concentrically relative to one another and are axially aligned with one another to provide a straight through, low restriction, free flow path for engine exhaust through the catalytic converter and resonator combination 60, essentially in the manner of the gas flow provided in the converter and resonator combination device 10 of Figure 1.

Engine exhaust gases flow through the device 60 of Figure 2 generally in the manner described for the exhaust gas flow through the converter and resonator 10 of Figure 1, as indicated by the exhaust gas arrows G. While the small perforations 80 are adapted to attenuate sounds of a certain predetermined frequency range, it will be seen that some exhaust gases G will flow through these passages 80. However, this is of no consequence, because as gas pressure equalizes within the plenum 86 between the resonator element 72 and the outer shell 62, those gases will flow back through the resonator perforations 80 to be entrained in the exhaust gas flow G as it passes through the resonator element 72.

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The above described construction for the combination catalytic converter and resonator combination 60 of Figure 2, provides a means of adjusting the length of the resonator element 72 within the outer shell 62 of the device 60 during manufacture or assembly. The resonator forward end support plate 82 may be welded or otherwise suitably secured to the forward end 76 of the resonator element 72, and the assembly inserted into the outer shell 62 of the device 60 before the conical rearward ~~end~~ section 70 is welded to the rearward ~~end~~ portion 68 of the outer shell or canister 62. At this point, the rearward conical ~~end~~ section 70 is welded in place, with the rearward or outlet portion or end 78 of the resonator tube element 72 extending outwardly past the smaller diameter trailing ~~end~~ portion 84 of the ~~rearward element~~ conical section 70 of the shell or canister 62.

It will be seen that at this point, the resonator element 72 and its attached forward end support plate or toroidal front plate 82 may be adjusted or repositioned as desired axially within the outer shell or canister 62, as indicated by the adjustment arrow A in Figure 2. This allows the resonator element 72 to be positionally adjusted to a predetermined position as desired, in order to achieve the attenuation of sound within a certain predetermined frequency range. Extending the resonator element 72 rearwardly from the rearward portion ~~70~~ 68 of the device 60 (with less of the element 72 residing within the plenum 86) results in the attenuation of relatively higher frequencies, while inserting the resonator element 72 into the interior of the shell 62 results in the attenuation of relatively lower frequencies.

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The seam or joint defined by the smaller diameter rearward end 84 of the conical rearward ~~end~~ section 70 of the outer shell or canister 62 and the unperforated rearward end portion 78 of the resonator element 72, is then welded to provide a leakproof seal and to immovably affix the resonator element 72 in place. Thus, the catalytic converter and resonator combination device 60 of Figure 2, may be adjustably tuned for each specific engine and vehicle application for which it is manufactured, in order to achieve the optimum sound attenuation in the frequency range desired.

While the above described adjustment of the resonator element 72 within the shell or canister 62 affects the attenuated frequency range of the device 60 to a great extent, it has very little, if any, effect on the volume of sound which emanates from the device 60. As there is no structure within the toroidal plenum 86 surrounding the resonator element 72, there may be a certain amount of sound which radiates from the resonator element 72, through the plenum 86, and outwardly through the walls of the outer shell or canister 62. Accordingly, the plenum ~~volume~~ 86 may be filled, at least to a certain degree as desired, with a sound absorbing material 90, in order to dampen the volume of sound which may emanate from the device 60. Such material may comprise glass fiber, corrosion resistant metal strands ("stainless steel wool"), spun fibers or strands of a rock or stone material such as basalt ("rock wool"), or other suitable material which is capable of retaining its structure when subjected to the high temperatures occurring within the present device 60.

The above described embodiments each include a single resonator tube element 34 or 72 with a single catalytic converter element 24 concentric therewith. However, it will be seen that additional catalytic converter elements may be added in series with the single catalytic converter element 24 of the devices 10 and 60 respectively of Figures 1 and 2, if so desired, for further efficiency. Figure 3 discloses such an alternate embodiment, designated as catalytic converter and resonator combination 100.

The catalytic converter and resonator combination 100 is constructed generally along the lines of the converter and resonator 10 of Figure 1, comprising a canister or shell 102 with an inlet end 104, forward portion 106, rearward portion 108, and outlet end 110. The canister forward portion 106 is actually divided into two separate portions, respectively 112 and 114, each having a catalytic converter, respectively 116 and 118, affixed therein, with each sealed about its periphery in the manner of the single catalytic converter 24 within the forward portion 16 of the converter and resonator combination 10 of Figure 1. The two catalytic converter elements 116 and 118 may be spaced apart by a catalytic converter plenum 120 disposed therebetween, if desired. Alternatively, the two converters 116 and 118 may be positioned immediately adjacent one another, in order to transfer heat generated by the catalytic reactions therein to one another for greater efficiency. A catalytic converter and resonator plenum 122 may be provided behind the second converter 118, in the manner of the converter and resonator plenum 52 of the converter and resonator 10 of Figure 1.

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Each of the catalytic converter elements 116 and 118 includes a substrate, respectively 124 and 126. These two substrates 124 and 126 are preferably formed in the manner described further above for the substrate 28 of the catalytic converter 24 of Figure 1, i.e., having relatively thin walls and relatively large passage widths therebetween, as illustrated in Figure 5. A ceramic material, such as the Dow-Corning XT (tm), such as cordierite ceramic, described further above, may be used to form the substrates 124 and 126 of the embodiment 100 of Figure 2. If desired, the two substrates 124 and 126 may utilize different coatings or washes of catalytic materials or elements thereon, and/or in different concentrations, in order to catalyze different exhaust products to differing degrees in each of the two converters 116 and 118. It will be seen that additional catalytic converter elements, not shown, may be placed in series with the two catalytic converter elements 116 and 118 of the catalytic converter and resonator combination 100 of Figure 3, if so desired, for further efficiency in processing exhaust emissions.

The rearward portion 108 of the canister 102 contains an axially concentric resonator tube or pipe element 128 having a plurality of noise attenuating perforations 130 therein. The resonator element 128 is affixed within the canister rearward portion 108 by a forward and a rearward toroidal plate, respectively 132 and 134, as in the converter and resonator combination 10 of Figure 1. A resonator plenum 136 is defined between the resonator element 128 and the canister rearward portion 108, similar to the equivalent construction shown in Figure 1.

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As in the catalytic converter and resonator combination 10 of Figure 1, the forward resonator tube retaining plate or forward toroidal plate 132 is preferably formed with a solid, impermeable periphery, to preclude exhaust gases from flowing directly into the resonator plenum 136 from the catalytic converter and resonator plenum 122. a4 However, the rear retaining plate or rearward toroidal plate 134 may be provided with a series of peripheral passages 138 therethrough, in the manner of the rear plate 50 of the converter and resonator combination 10 of Figure 1, in order to allow any small amount of gases passing into the resonator plenum 136 to escape therefrom.

The catalytic converter and resonator combination 100 of Figure 3 functions essentially like the converter and resonator 10 of Figure 1, with exhaust gases G entering the canister 102 through the inlet end 104, and thence passing through the two catalytic converters 116 and 118. The converters 116 and 118 (and/or others) serve to react the exhaust gases G catalytically, whereupon the gases G pass into the catalytic converter and resonator plenum 122 and rearwardly through the resonator element 128. The noise level of the exhaust is canceled or attenuated in a frequency range (generally relatively higher frequencies) according to the spacing and dimensions of the perforations 130 of the resonator element 128. The gases G then exit the catalytic converter and resonator combination 100 from the rear or outlet end 110 of the canister 102, to pass into the remainder of the exhaust system.

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Figures 4 and 5 illustrate two further embodiments of the present invention, for dual exhaust systems having a pair of inlet pipes and a corresponding pair of outlet pipes. The catalytic converter and resonator of Figure 4, designated by the reference numeral 200, will be seen to have a single catalytic converter element therein, but includes a pair of resonator elements. The catalytic converter and resonator 200 is constructed somewhat along the lines of the converter and resonator 10 of Figure 1, comprising a canister or shell 202 with an inlet end 204, forward portion 206, rearward portion 208, and outlet end 210. However, it will be seen that the inlet and outlet ends 204 and 210 each respectively comprise a pair of laterally joined, truncated, conically shaped shells blending together to smoothly join the oval shaped canister portion 202. The inlet and outlet ends 204 and 210 each have a pair of cylindrical inlet and outlet pipes, respectively 212 and 214, extending therefrom. These twin inlet and outlet pipes 212 and 214 allow the catalytic converter and resonator combination 200 of Figure 4, to be installed in a dual exhaust system.

The catalytic converter element 216 of the converter and resonator combination 200 of Figure 4, will be seen to have an oval configuration closely fitting within and sealed to the forward portion 206 of the converter and resonator canister 202. Thus, exhaust gases cannot pass between the inner wall of the canister 202 ~~shell~~ and the outer wall of the catalytic converter element 216, but must pass through the substrate 218, as in the manner of the other embodiments.

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The substrate 218 of the catalytic converter element 216 is preferably constructed similarly to the substrates 28, 124, and 126 of the converter and resonator devices 10 and 100 discussed further above, i. e., preferably formed of a ceramic material such as Dow-Corning XT (tm), such as cordierite ceramic, with relatively thin walls to allow the substrate to heat rapidly for maximum efficiency, and with relatively wide passages (preferably greater than .040 inch) therethrough for reducing exhaust gas flow restriction as much as possible. A catalytic converter and resonator plenum 220 may be provided behind the converter element 216, in the manner of the converter and resonator plenum 52 of the converter and resonator 10 of Figure 1.

The canister rearward portion 208 contains first and second laterally spaced, axially concentric resonator pipe elements, respectively 222 and 224, each having a plurality of noise attenuating perforations 226 therein. The resonator elements 222 and 224 are affixed within the canister rearward portion 208 by a forward and a rearward plate, respectively 228 and 230, as in the converter and resonator combination 10 of Figure 1. Instead of the toroid shaped plates of the catalytic converter and resonator combinations 10 and 100 of Figures 1 and 3, the two plates 228 and 230 each have an oval peripheral shape, to fit closely within the oval shaped canister 202. Each plate 228 and 230 includes a pair of laterally spaced apart resonator passages therethrough, for exhaust gases to pass from the converter and resonator plenum 220 into the two resonator elements 222 and 224, and from the resonator elements 222 and 224, into the canister outlet portion 210.

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A resonator sound attenuating plenum 232 is defined between the first and second resonator elements 222 and 224 and the canister rearward portion 208, similar to the equivalent construction shown in Figure 1. The plenum 232 of the converter and resonator combination 200 of Figure 4 serves essentially the same function as the plenum 44 of the device 10 of Figure 1, i. e., to attenuate exhaust noise or sound of a predetermined frequency range, before the exhaust gases leave the device. However, it will be noted that the plenum 232 of the device of Figure 4 is somewhat larger than that of the other two converter and resonator combination devices 10 and 100 described further above, since the surrounding canister 202 does not encircle only a single resonator element.

The resulting relatively large plenum 232 may be desirable, with pressure waves from the two resonator elements 222 and 224 perhaps canceling one another in the central area of the plenum 232 between the two resonator tubes 222 and 224. However, it is possible that amplification of certain frequencies might also occur under certain conditions, and accordingly, it may be desirable to divide the single large plenum 232 with a longitudinal baffle 234 (shown as an optional component, in broken lines in Figure 4) in order to separate the two resonator elements 222 and 224. The baffle 234 may extend forwardly of the forward resonator attachment plate 228, if so desired, to divide the converter and resonator plenum as well.

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The forward resonator tube retaining plate 228 may be formed with a solid, impermeable periphery, as in the catalytic converter and resonator combination 10 of Figure 1. However, an alternative is shown in the converter and resonator embodiment 200 of Figure 4, in which both the front and rear plates 228 and 230 include a plurality of peripheral passages, respectively 236 and 238, therethrough, in the manner of the rear plate 50 of the converter and resonator combination 10 of Figure 1, in order to allow any small amount of gases passing into the resonator plenum 232 to escape therefrom.

The catalytic converter and resonator combination 200 of Figure 4 functions essentially like the converter and resonator 10 of Figure 1, with exhaust gases G entering the canister 202 through the dual inlet pipes 212 of the inlet end 204, and thence passing through the single catalytic converter element 216. (While the single oval shaped converter element 216 is generally shaped to fit more conventional catalytic converters, it will be seen that the dual resonator embodiment 200 of Figure 4 could be constructed with the forward portion 206 of the canister 202 configured with two adjacent cylindrically shaped areas, to accept two laterally spaced cylindrical converter elements configured somewhat like the converter elements 24, 116, and 118 of Figures 1 and 2, if so desired.)

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The converter element 216 serves to react the exhaust gases G catalytically, whereupon the gases G pass into the catalytic converter and resonator plenum 220 and rearwardly through the two resonator elements 222 and 224. The noise level of the exhaust is canceled or attenuated in a frequency range (generally relatively higher frequencies) according to the spacing and dimensions of the perforations 226 of the two resonator elements 222 and 224, and the installation of a dividing baffle 234 (if any) therebetween. The gases G then exit the catalytic converter and resonator combination 200 from the rear or outlet end 210 and corresponding outlet pipes 214 of the canister 202, to pass into the remainder of the exhaust system.

The axially parallel configuration of the inlet pipes 212, substrate passages of the catalytic converter element 216, dual resonator elements 222 and 224, and outlet pipes 214, serve to provide the least possible change of direction for exhaust gases G flowing through the catalytic converter and resonator combination 200 of Figure 4. In fact, other than some mixing and expansion which may occur in the plenums of the device 200 of Figure 4, the components of the two basic exhaust gas passages defined by each corresponding inlet and outlet pipe 212 and 214, are precisely axially aligned with one another. Preferably, the canister shell 202, resonator elements 222 and 224, forward and rearward resonator attachment plates 228 and 230, and longitudinal resonator plenum baffle 234 (if installed) are all formed of corrosion resistant (stainless) steel, although other materials may be used if desired.

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The catalytic converter and resonator combination embodiment 300 of Figure 5, will be seen to be similar to the converter and resonator combination embodiment 200 illustrated in Figure 4 and discussed above, and closely related to the catalytic converter and resonator combination embodiments 10, 60, and 100, respectively of Figures 1, 2, and 3. However, rather than having only a single oval shaped converter element installed in the forward portion of the canister, the converter and resonator combination 300 of Figure 5 includes a pair of catalytic converter elements in tandem, somewhat along the lines of the catalytic converter and resonator combination device 100 illustrated in Figure 3.

The catalytic converter and resonator 300 is constructed somewhat along the lines of the converter and resonator 200 of Figure 4, comprising a generally oval shaped canister or shell 302 with an inlet end 304, forward portion 306, rearward portion 308, and outlet end 310. However, it will be seen that the inlet and outlet ends 304 and 310 each respectively comprise a pair of laterally joined, truncated, conically shaped shells blending together to smoothly join the oval shaped canister ~~portion~~ 302. The inlet and outlet ends 304 and 310 each have a pair of cylindrical inlet and outlet pipes, respectively 312 and 314, extending therefrom. These twin inlet and outlet pipes 312 and 314 allow the catalytic converter and resonator combination 300 of Figure 5, to be installed in a dual exhaust system.

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Rather than the single catalytic converter elements 24 and 216 of the converter and resonator combination embodiments 10, 60, and 200 respectively of Figures 1, 2, and 4, the canister forward portion 306 of the catalytic converter and resonator combination 300 of Figure 5 is actually divided into two separate portions, respectively 316 and 318, each having a catalytic converter element, respectively 320 and 322, affixed therein. Each catalytic converter element 320 and 322 is sealed about its periphery in the manner of the single catalytic converter 24 within the forward portion 16 of the converter and resonator combination 10 of Figure 1, and other embodiments discussed further above.

The two catalytic converter elements 320 and 322 may be spaced apart by a catalytic converter plenum 324 disposed therebetween, if desired. Alternatively, the two converters 320 and 322 may be positioned immediately adjacent one another, in order to transfer heat generated by the catalytic reactions therein to one another for greater efficiency. A catalytic converter and resonator plenum 326 may be provided behind the second converter 324, in the manner of the converter and resonator plenum 52 of the converter and resonator 10 of Figure 1.

It will be seen that the catalytic converter and resonator combination embodiment 300 of Figure 5 may be constructed to have a greater length for the inclusion of additional catalytic converter elements (not shown), if desired, in a similar manner to the alternative construction of the catalytic converter and resonator combination 100 of Figure 3, discussed further above.

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Each catalytic converter element 320 and 322 includes a substrate, respectively 328 and 330. These two substrates 328 and 330 are preferably formed in the manner described further above for the substrate 28 of the catalytic converter 24 of Figure 1, i.e., having relatively thin walls and relatively large passage widths therebetween, as illustrated in Figure 6. A ceramic material, such as the Dow-Corning XT(tm), such as cordierite ceramic, described further above, may be used to form the substrates 328 and 330 of the embodiment 300 of Figure 5. If desired, the two substrates 328 and 330 may utilize different coatings or washes of catalytic materials or elements thereon, and/or in different concentrations, in order to catalyze different exhaust products to differing degrees in each of the two converters 320 and 322. As noted further above, additional catalytic converter elements, not shown, may be placed in series with the two catalytic converter elements 320 and 322 of the catalytic converter and resonator combination 300 of Figure 5, if so desired, for further efficiency in processing exhaust emissions.

The two catalytic converter elements 320 and 322 of the converter and resonator combination 300 of Figure 5, each have an oval configuration closely fitting within and sealed respectively within the first and second catalytic converter portions 316 and 318 of the converter and resonator canister 302. Thus, exhaust gases cannot pass between the inner wall of the canister 302 shell and the outer walls of the two catalytic converter elements 320 and 322, but must pass through the respective substrates 328 and 330, as in the manner of the other embodiments.

The two substrate elements 328 and 330 of the respective catalytic converter elements 320 and 322 are preferably constructed similarly to the substrates 28, 124, 126, and 218 of the converter and resonator devices 10, 60, 100, and 200 discussed further above, i. e., preferably formed of a ceramic material such as Dow-Corning XT (tm), such as cordierite ceramics with relatively thin walls to allow the substrate to heat rapidly for maximum efficiency, and with relatively wide passages (preferably greater than .040 inch) therethrough for reducing exhaust gas flow restriction as much as possible.

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The canister rearward portion 308 contains first and second laterally spaced, axially concentric resonator pipe elements, respectively 332 and 334, each having a plurality of noise attenuating perforations 336 therein. The resonator elements 332 and 334 are affixed within the canister rearward portion 308 by a forward and a rearward plate, respectively 338 and 340, as in the converter and resonator combination 200 of Figure 4, and others. Instead of the toroid shaped plates of the catalytic converter and resonator combinations 10, 60, and 100 respectively of Figures 1, 2, and 3, the two plates 338 and 340 each have an oval peripheral shape, to fit closely within the oval shaped canister 302. Each plate 338 and 340 includes a pair of laterally spaced apart resonator passages therethrough, for exhaust gases to pass from the converter and resonator plenum 326 into the two resonator elements 332 and 334, and from the resonator elements 332 and 334, into the canister outlet portion 310.

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A resonator sound attenuating plenum 342 is defined between the first and second resonator elements 332 and 334 and the canister rearward portion 308, similar to the equivalent construction shown in Figure 3. The plenum 342 of the converter and resonator combination 300 of Figure 5 serves essentially the same function as the plenum 232 of the device 200 of Figure 4, i.e., to attenuate exhaust noise or sound of a predetermined frequency range, before the exhaust gases leave the device. The plenum 342 of the device of Figure 5 is configured much the same as the plenum 232 of the converter and resonator combination 200 of Figure 4, due to the similar configuration of the remainder of the two devices. A longitudinal baffle 344 (shown optionally, in broken lines) may be installed between the two resonator elements 332 and 334 to divide the single large plenum 342, in the manner and for the purposes of the optional baffle 234 of the catalytic converter and resonator combination 200 shown in Figure 4.

The forward resonator tube retaining plate 338 may be formed with a solid, impermeable periphery, as in the catalytic converter and resonator combination 10 of Figure 1. However, an alternative is shown in the converter and resonator embodiment 300 of Figure 5, in which both the front and rear plates 338 and 340 include a plurality of peripheral passages, respectively 346 and 348, therethrough, in the manner of the rear plate 50 of the converter and resonator combination 10 of Figure 1, in order to allow any small amount of gases passing into the resonator plenum 342 to escape therefrom.

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The catalytic converter and resonator combination 300 of Figure 5 functions essentially like the converter and resonator 100 of Figure 3, with exhaust gases G entering the canister 302 through the dual inlet pipes 312 of the inlet end 304, and thence passing through the two catalytic converter elements 320 and 322. (While the two oval shaped converter elements 320 and 322 are generally shaped to fit more conventional catalytic converters, it will be seen that the dual resonator embodiment 300 of Figure 5 could be constructed with the forward portion 306 of the canister 302 configured with two adjacent cylindrically shaped areas, to accept two laterally spaced cylindrical converter elements configured somewhat like the converter elements 24, 116, and 118 of Figures 1 and 3, if so desired.)

The converter elements 320 and 322 serve to react the exhaust gases G catalytically, whereupon the gases G pass into the catalytic converter and resonator plenum 326 and rearwardly through the two resonator elements 332 and 334. The noise level of the exhaust is canceled or attenuated in a frequency range (generally relatively higher frequencies) according to the spacing and dimensions of the perforations 336 of the two resonator elements 332 and 334, and the installation of a dividing baffle 344 (if any) therebetween. The gases G then exit the catalytic converter and resonator combination 300 from the rear or outlet end 310 and corresponding outlet pipes 314 of the canister 302, to pass into the remainder of the exhaust system.

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The axially parallel configuration of the inlet pipes 312, substrate passages of the two catalytic converter elements 320 and 322, dual resonator elements 332 and 334, and outlet pipes 314, provide the least possible change of direction for exhaust gases G flowing through the catalytic converter and resonator combination 300 of Figure 5. In fact, other than some mixing and expansion which may occur in the plenums of the device 300 of Figure 5, the components of the two basic exhaust gas passages defined by each corresponding inlet and outlet pipe 312 and 314, are precisely axially aligned with one another. As in the case of the other embodiments discussed further above, various sheet metal components are preferably formed of corrosion resistant (stainless) steel, although other materials may be used if desired.

A test of one of the dual resonator embodiments of the present catalytic converter and resonator combination was performed on August 12, 1997, to measure the exhaust emissions from an engine E to which the present invention was connected. (Comparable results would be expected from the other embodiments when installed in a compatible exhaust system.) Testing was performed on an automobile (1992 Morocco Corvette ~~Marocco~~) using an engine from a 1992 General Motors (GM) OEM ~~Chevrolet~~ Corvette, with the engine meeting the emissions regulations for that model year. The test configuration was somewhat along the lines of the assembly shown in Figure 8, with the converter and resonator combination, e.g., embodiment 300, being connected to the exhaust system of an engine E, somewhat downstream of the engine E in the general location of a conventional resonator installation.

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A muffler M was installed at the downstream end of the system. While a conventional pre-catalytic P and catalytic converter C are shown in Figure 8, it should be noted that these two components are not necessarily required with the present catalytic converter and resonator combination in any of its embodiments, but may be installed therewith if so desired or required. While the muffler M may be desirable for further noise reduction, it should be noted that the combination of the present catalytic converter and resonator, with either a pre-catalytic converter and/or another catalytic converter, may obviate need for further noise reduction means, particularly if additional sound absorbent material is installed. Test results are provided in Table I, following.

TABLE I. EXHAUST EMISSIONS TEST RESULTS

	TOTAL HYDROCARBONS	CARBON MONOXIDE	OXIDES OF NITROGEN	NON-METHANE HYDROCARBONS
1992 CALIF. AIR RESOURCES BOARD STANDARDS (grams/mile)	0.41	3.40	1.00	(Not tested in 1992)
LOW EMISSIONS VEHICLE	0.41	3.40	0.20	0.075
ULTRA LOW EMISSIONS VEHICLE	0.41	1.70	0.20	0.040
1992 GENERAL MOTORS (GM) OEM CORVETTE (90 seconds to closed loop)	0.33	1.82	0.63	(Not tested in 1992)
1992 MOROCCO CORVETTE ~~MAROCCO~~, CATALYTIC CONVERTER AND RESONATOR (240 seconds to closed loop)	0.08	0.58	0.63	0.069

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It should be noted that the 1992 ~~Marocco~~ Morocco Corvette is an exotic, high performance automobile which uses the engine and drivetrain components from a 1992 General Motors (GM) OEM ~~Chevrolet~~ Corvette, including the six speed manual transmission of that drivetrain. This transmission includes a "skip shift" pattern which electronically induces a second gear lockout when the car is shifted from first gear at relatively low throttle openings and engine speed, in order to meet the CAFE (Corporate Average Fuel Economy) requirements without penalty. Thus, the transmission is shifted from first to fourth gear, rather than being sequentially shifted from first to second gear.

However, the above noted test results for the 1992 General Motors (GM) OEM Corvette did not use the skipped shift pattern during the time the engine was not fully warm, but rather used a sequential shift pattern. This enabled the 1992 General Motors (GM) OEM Corvette to warm up more quickly, requiring only 90 seconds to attain "closed loop" status with the emissions control components being fully heated, to meet the emissions standards as required. The 1992 ~~Marocco~~ Morocco Corvette utilized the skipped shift pattern, going from first directly to fourth gear, throughout this test. It appears that this caused the engine to warm more slowly, resulting in the electronic controls for the emissions requiring a full 240 seconds to attain "closed loop" status, when the catalytic converter was completely heated. This appears to be the cause for the relatively high oxides of nitrogen emissions component. Further testing is planned in order to check this factor.

Another factor in the above test was an additional catalytic converter component installed on the 1992 Morocco Corvette ~~Marocco~~ car, comprising a combination pre-catalytic converter and catalytic converter device. An exhaust and emissions system engineer was consulted and found that the present catalytic converter and resonator combination was responsible for about 30 percent of the reduction in emissions of the car. Thus, factoring out the approximately 70 percent emissions reduction due to the pre-catalytic converter and catalytic converter combination installed on the 1992 Morocco Corvette ~~Marocco~~, would result in total hydrocarbon and carbon monoxide emissions respectively of 0.27 and 1.67 grams/mile, which still betters both the 1992 General Motors (GM) OEM Corvette emissions test results and the ultra low emissions vehicle standards.

Although the test standards did not allow the 1992 Marocco car equipped with the present catalytic converter and resonator combination to be measured by the same standards as the 1992 General Motors (GM) OEM Corvette, it should be noted that with the exception of the oxides of nitrogen emissions component, the system meets or exceeds the standards for ultra-low emissions vehicles planned for the future. Also, even though the testing of the 1992 Morocco Corvette ~~Marocco~~ was not conducted to the same standards as that of the 1992 General Motors (GM) OEM Corvette, the 1992 Morocco Corvette ~~Marocco~~ equipped with the present catalytic converter and resonator combination, bettered the exhaust emissions measured from the 1992 General Motors (GM) OEM Corvette for total hydrocarbons and carbon monoxide, even when factoring out emissions reductions due to other emissions control devices installed on the 1992 Morocco Corvette ~~Marocco~~ automobile.

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In summary, the present catalytic converter and resonator combination result in superior exhaust emissions control for an internal combustion engine. The installation of one or more catalytic converter elements with one or more resonator pipe elements, in the area where such systems are typically installed along the mid portion of an automobile exhaust system, results in the catalytic converter element(s) receiving sufficient exhaust heat to provide significant reductions in exhaust emissions, while simultaneously controlling noise with the resonator component. The present device may be used with other exhaust emissions and noise control devices, or may be used as a stand alone system, pending testing which may find that further emissions and sound controls are not required on certain automobiles and engines.

The present catalytic converter and resonator combination in any of its embodiments may also be constructed to provide for the adjustment or tuning of the resonator element within the outer shell or canister, at the time of manufacture or assembly. In this manner, the present invention may be tuned to a predetermined configuration in order for the resonator to attenuate exhaust sounds in a predetermined frequency range as desired, to suit specific engine and/or vehicle configurations. Also, any of the embodiments described herein may be provided with some form of sound insulation material disposed within the plenum surrounding the resonator element(s), in order to attenuate the volume of exhaust sound emanating from the device.

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The use of a strong and durable material which is capable of withstanding extremely high temperatures, enables the substrates of the present catalytic converter components to be constructed with thinner walls, and thus larger passages therethrough, to reduce restrictions to exhaust gas flow through the components. The relatively thin walls of the substrates, with their relatively high surface area to mass and volume ratios, allow them to heat up more quickly to achieve further gains in catalytic reaction efficiency. The effect of the present catalytic converter and resonator combination invention, in any of its embodiments, enables essentially conventional internal combustion engines to meet or exceed the standards set for ultra low emissions vehicles, and will result in a cleaner, healthier environment when motor vehicles are equipped with the system of the present invention.

It is to be understood that the present invention is not limited to the sole embodiments described above, but encompasses any and all embodiments within the scope of the following claims.

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